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# Review of augmentation of energy needs using renewable energy sources in India

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**Abstract**

Sustainable and equitable development is the most important challenge before mankind. After food, most pressing concern is energy for a decent living. The energy consumption has been recognized world wide as a parameter of development in a society. In the present paper an attempt has been made to review the demand of energy, the potential of renewable energy sources in India and its prospects for development in cost effective and sustainable manner.


*Keywords:* Renewable energy; Installed capacity; Electricity; Cost

**Contents**



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## 1. Introduction

Increasing demand of energy and negative impacts of fossil fuels on the environment has emphasized the need of harnessing energy from renewable sources. The world is passing through a critical period when conventional and exhaustible sources of energy are getting depleted at a very fast rate, which has focused attention to the non-exhaustible and renewable sources of energy. Renewable energy resources, which the country has in abundance, such as solar, wind, biomass, small hydro, etc. are non-depletable, and can effectively meet energy demand and are environmentally benign. They can create a significant impact in the generation of grid electricity, as progress in wind power, solar, small hydro, biomass power and bagasse co-generation has demonstrated in the last few years. About 5700 MW of power generating capacity based on renewable energy sources (RES) has been installed in the country so far. This constitutes about 5% of the total installed capacity [1].

RES (like biomass, solar, wind, etc.) that use indigenous resources have the potential to provide energy with negligible emissions of air pollutants and green house gases. Currently, RES supply 16% of the total world energy demand [2]. The political support for renewable energies has been growing continuously both at the national and international level to promote renewable energy. India's population of more than 1028 million is growing at an annual rate of 1.58%. As fossil fuel energy becomes scarcer, India will face energy shortages significantly due to increase in energy prices and energy insecurity with in the next few decades. In addition, continued reliance on fossil fuel consumption will contribute to accelerating the rates of domestic environmental quality and global warming. For these reasons the development and use of RES & Technologies are becoming vital for sustainable economic development of India.

India's geographic location has several advantages for the extensive use of the RES. India has an area of 3,287,590 km$^2$ in which land area is 2,973,190 km$^2$ and water area is 314,400 km$^2$. It is 7th in the world. The length of the coastline is 7000 km the climate varies from tropical monsoon in south to temperate in north. India share boundaries with Bangladesh 4053 km, Burma 1463 km, Bhutan 605 km, China 3380 km, Nepal 1690 km and with Pakistan 2912 km. India's economy encompasses traditional village farming, modern agriculture, handicrafts, a wide range of modern industries and a multitude of support services. Government controls have been reduced on foreign trade and investment and privatization of domestic output has proceeded slowly. The economy has posted an excellent average growth rate of 6% since 1990, reducing poverty by about 10 percentage points. India is capitalizing on its large numbers of well-educated people skilled in the English language to become a major exporter of software services and software workers. GDP growth in India averaged 4.8 annually from 1971 to 1990. It accelerated in 1993, and averaged 7% year in the 1993–97 period, followed by a slight slow down in 1998 and 1999. However, high population growth has dampened per capita income. Although it is the world's fifth largest economy. India is below the top 100 countries in terms of per capita GDP, substantially lower than the developing world average. According to the World Bank, India has the largest concentration of poverty, with more than a third of its population living below the poverty line. India accounts for 40% of the world's poor [3,4].

## 2. Energy overview of India

India is a net energy importer, mostly due to the large imbalance between oil production and consumption. India is presently the world's sixth greatest consumer of energy, accounting for slightly more than 3% of the world's total annual energy consumption. India's crude oil reserves are currently estimated at 4.7 billion barrels. India's natural gas reserves are currently estimated at 22.9 trillion cubic feet (tcf). India has huge coal reserves, about 7% of the world's total. At the current level of production and consumption, India's coal reserves would last for nearly three century. Hard coal reserves total almost 214 billion tons (as on January 2001), of this 84 billion tons are proven recoverable reserves anthracite and bituminous coal, with another 28 billion tons of lignite reserves. An historical summary of India's total primary energy production (TPEP) and consumption (TPEC) is shown in Table 1.

India's need for power is growing at a prodigious rate, annual electricity generation and consumption have nearly doubled since 1990, and it is projected 2.6 (low end)–4.5% (high end). Annual rate of increase for electricity consumption is the highest for any major country. India is currently the seventh greatest electricity consuming country (accounting for about 3.5% of the world total annual electricity consumption) but will soon overtake both Germany and Canada in that regard. India now faces electricity shortages conservatively estimated at 11% and as high as 18% during peak demand periods. Fig. 1 shows the electricity generation from various sources and consumption during year 1990–2002 [3,4].

For four decades, India's state run electrical system sought to expand power at minimum cost to the poor. As of 2000, India's electricity system extended to 87% of India's villages, but only to one-third of rural households. With its size, fast growth in energy demand and the significance of coal in its fuel use, India has also become a major contributor to global GHG emissions as shown in Table 2. Despite its extremely low per capita $CO_2$ emissions, India contributed 4% of the total world $CO_2$ emissions in 1997 [5,6]. Table 3 shows the installed capacity in India in different periods [7].

## 3. Future demand

Expert consultation at the Asia Energy Vision 2020, organized under the World Energy Council agreed on energy demand projection in India up to 2020 as given in Table 4 [8].

## 4. An overview of different renewable energy usage in India

There is a long history of renewable energy use in India including biomass, solar, geothermal, ocean, wind and small hydro. Renewable energy technologies produce marketable energy by converting natural phenomena/resources into useful energies. The

Table 1
India's TPEP and TPEC (in Quads)

| Year | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| TPEP | 6.57 | 6.86 | 7.17 | 7.37 | 7.63 | 9.01 | 8.83 | 9.05 | 9.03 | 9.18 | 9.48 |
| TPEC | 7.78 | 8.06 | 8.71 | 9.10 | 9.59 | 11.10 | 11.25 | 11.55 | 11.78 | 12.12 | 12.67 |

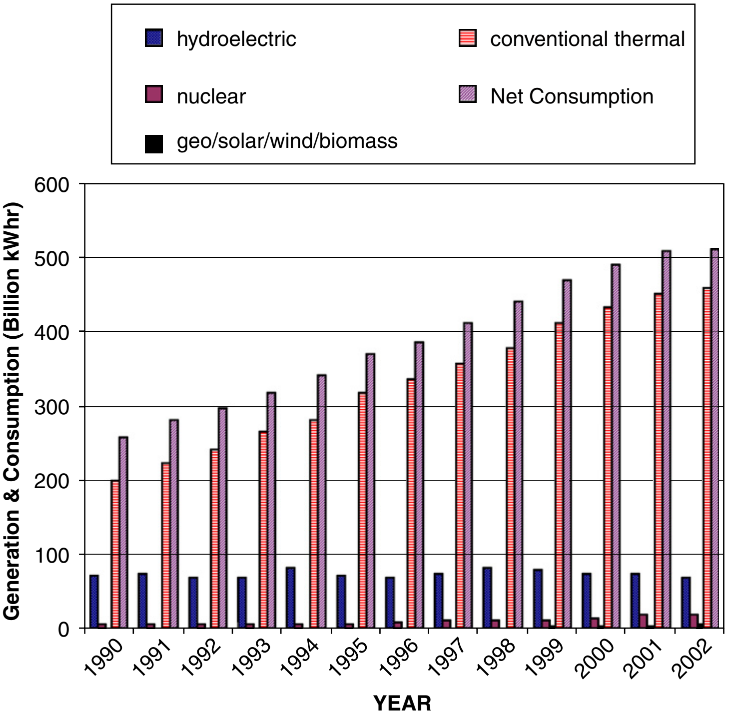



Fig. 1. Electricity generation and consumption in India (1990–2002).

Table 2
India in a global context (share and ranks in the world)

| Particulars | 1997 | | 2020 Share (%) | Increments Share (%) |
|---|---|---|---|---|
| | Share (%) | Rank | | |
| GDP in PPP terms | 4.0 | 5 | 5.9 | 7.6 |
| Population | 16.6 | 2 | 17.0 | 18.3 |
| TPES (excl. CRW) | 3.1 | 7 | 5.3 | 9.1 |
| Coal | 6.8 | 3 | 10.0 | 16.7 |
| Oil | 2.6 | 11 | 4.6 | 8.1 |
| Final electricity demand | 3.0 | 8 | 5.5 | 8.3 |
| CRW | 18.2 | 2 | 16.2 | 9.6 |
| TPES (inclusive CRW) | 4.8 | 5 | 6.3 | 11.9 |
| $CO_2$ emissions | 3.9 | 6 | 6.2 | 10.1 |

CRW—Combustible renewable & waste.

usage of renewable energy resources is a promising prospect for the future as an alternative to conventional energy. The Kyoto protocol has created favorable climate for mobilizing international support for renewable energy development. The clean development mechanism (CDM) was one of the awareness through which financial resources can be raised [1].

Table 3
Installed capacity in India in different periods [5]

| Sl. No. | Type of energy | Installed capacity (MW) | | |
|---|---|---|---|---|
| | | 31.3.1985 | 31.3.1990 | 31.3.2000 |
| 1 | Thermal | 27,082 | 43,081 | 70,186 |
| 2 | Hydro | 14,314 | 19,855 | 23,816 |
| 3 | Nuclear | 1095 | 1800 | 2680 |
| 4 | Wind | — | — | 1154 |
| Total | | 42,491 | 64,736 | 97,836 |

Table 4
Energy demand projection in India

| Sl. no. | Source | Unit | 1991–92 | 1996–97 | 2009–10 | 2020–21 |
|---|---|---|---|---|---|---|
| 1 | Electricity | TWh | 231 | 336 | 725 | 1300 |
| 2 | Coal | Mt. | 229 | 311 | 690 | 1345 |
| 3 | Petroleum products | Mt. | 57 | 81.2 | 165 | 335 |
| 4 | Natural gas | b cum | 18.6 | 30.2 | 65 | 130 |

### *4.1. Solar energy*

Solar energy in India is in abundance. Most parts of India get 300 days of sunshine a year. India receives solar energy equivalent to over 5000 trillion kWh/year, which is far more than the total energy consumption of the country. There is a large market for photo voltaic (PV) technology and progress has been made in the deployment of small, stand-alone PV systems. A total of 58 MWe capacity has been installed through 750,000 systems including solar lanterns, home lightning systems, street lightning systems, water pumping systems, small power plants and 1.1 MWe in various applications.

### *4.2. Biomass*

Biomass defined as all land- and water-based vegetation as well as organic wastes, fulfilled almost all of human kind's energy need prior to the industrial revolution. There are basically three distinct sources of biomass energy: municipal and industrial wastes, agricultural crop residue and energy plantations. Many different types of biomass can be grown for the main purpose of energy production. Crops that have been used for energy include: sugarcane, corn, sugar beats, grains and many others. There are two main factors, which determine whether a crop is suitable for energy use. Good energy crops have a very high yield of dry material per unit of land (dry ton/ha).

Biomass energy and co-generation programme is being implemented with the main objective of promoting technologies for optimum use of country's biomass resources and the exploitation of the biomass power generation potential, estimated at 19,500 MW. Accurate information on availability of biomass in different parts of the country, which could be made available for energy purposes, is a prerequisite for promotion of

commercial projects. A biomass power/co-generation capacity addition of 115 MW in six states was created in the country during the year 2004, against a target of 125 MW for the whole. The cumulative biomass power/bagasse co-generation-based power generation capacity in the country has now reached 437 MW. The details of biomass and co-generation energy capacity installed in different states of India are given in Table 5.

### 4.3. Wind energy

Among the different RES, wind energy is currently making a significant contribution to the installed capacity of power generation and is emerging as a competitive option. India with an installed capacity of about 3000 MW ranks fifth in the world after Germany, USA, Spain and Denmark. India has been harnessing wind energy for hundreds of years. From ancient time windmills, making use of wind energy had been used for pumping water and grinding grain. Today, the windmill's modern equivalent, wind turbine, generates electricity from wind energy. Advanced wind turbine technologies are able to produce electricity for homes, business and for utilities. The coastline is the most conducive for large-scale wind energy development.

Wind turbines can be used as stand-alone applications, or they can be connected to a utility power grid or even utilized as a hybrid system with a PV. For utility scale sources of wind energy, a large number of wind turbines are built in array close proximity to form a wind farm. Constraints in windmill development may occur during the public consideration process in coastal areas, which are used as resorts. Noise pollution may be a problem in areas situated close to residential districts. Wind energy can be feasible where the average wind velocity is higher than 5–6 m/s. If all economically feasible land sites were development, the full potential of wind power production would be about 45,000 MWe in India.

The environmental impacts of wind energy production include site selection of the wind turbines in or near the flyways of migrating birds and wildlife refuges, electromagnetic interference with television and radio signals within 2–3 km of large installations, and noise of rotating blades. Development of non-conventional energy sources has identified 192

Table 5
Installed capacity of biomass/co-generation plants in India

| Sl. No | State | Biomass (MW) | Co-generation (MW) |
|---|---|---|---|
| 1 | Andhra Pradesh | 182.2 | 63.00 |
| 2 | Chattisgarh | 11.00 | — |
| 3 | Gujarat | 0.50 | — |
| 4 | Haryana | 4.00 | 2.00 |
| 5 | Karnataka | 36.00 | 116.00 |
| 6 | Madhya Pradesh | 1.00 | — |
| 7 | Maharashtra | 3.50 | 32.50 |
| 8 | Punjab | 10.00 | 12.0 |
| 9 | Rajasthan | 7.80 | — |
| 10 | Tamil Nadu | 34.00 | 138.50 |
| 11 | Uttar Pradesh | — | 73.00 |
| | Total | 290.00 | 437.00 |

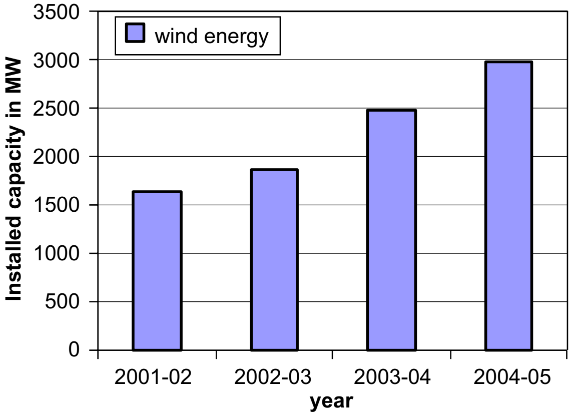



Fig. 2. Wind energy installations.

potential sites for wind stations with a total estimated potential of 20,000 MWe. Total installed capacity as a function of financial year is shown in Fig. 2.

### 4.4. Small hydropower

The main source of renewable electricity generation in India is hydropower. Regardless of the huge plans to develop wind energy, hydropower will continue to remain one of the biggest electricity generator. In India, it has been estimated that a potential of 15,000 MW exists in small hydro. Small hydropower plants built primarily on existing water ways constructed for irrigation purposes mainly using standard designs and energy facilities, supplying energy to the power grids are economically feasible and profitable. About 4233 potential sites each having capacity up to 25 MW have been identified in various parts of the country with a total potential of 10,324 MW. Thus far, 514 small hydro schemes with a total installed capacity of nearly 1693 MW are under operation and 159 schemes with another 490 MW are under various stages of implementation. Table 6 shows the details of small hydropower sites (up to 25 MW capacity) in each state identified, power stations set up and ongoing projects [1].

## 5. Cost and achievements of different RES

India has an established policy to tape the potential for RES. The Indian scientific establishment has been working on the development of various renewable energy systems. In 1981, the Government of India established a Commission for Additional Sources of Energy (CASE) in the Department of Science and Technology. The mandate of CASE is to promote R&D activities in the field of renewable energy. CASE was incorporated in 1982, in the newly created Department of non-conventional energy sources (DNES). In 1992, DNES became the Ministry for non-conventional energy sources. The Ministry continues to support the implementation of a large broad-spectrum programme coveting the entire range of new and renewable energies.

The cost of energy generation for various sources and achievements are shown in Tables 7 and 8 [1,9].

Table 6
State wise details of small hydropower development in India

| Sl. No. | State/UT | Projects identified | | Projects set up | | Projects ongoing | |
|---|---|---|---|---|---|---|---|
| | | No. | Capacity (MW) | No. | Capacity (MW) | No. | Capacity (MW) |
| 1 | Andhra Pradesh | 286 | 254.63 | 57 | 178.81 | 5 | 7.30 |
| 2 | Arunachal Pradesh | 492 | 1059.03 | 53 | 32.50 | 24 | 51.51 |
| 3 | Assam | 46 | 118.00 | 3 | 2.11 | 8 | 51.00 |
| 4 | Bihar | 92 | 194.02 | 5 | 45.90 | 9 | 14.00 |
| 5 | Chhattisgarh | 47 | 57.90 | 4 | 13.50 | 1 | 5.50 |
| 6 | Goa | 3 | 2.60 | 1 | 0.05 | — | — |
| 7 | Gujarat | 290 | 156.83 | 2 | 7.00 | — | — |
| 8 | Haryana | 22 | 30.05 | 5 | 62.70 | — | — |
| 9 | Himachal Pradesh | 323 | 1624.78 | 49 | 108.04 | 7 | 52.70 |
| 10 | Jammu & Kashmir | 201 | 1207.27 | 27 | 102.24 | 9 | 13.31 |
| 11 | Jharkhand | 89 | 170.05 | 6 | 4.05 | 8 | 34.85 |
| 12 | Karnataka | 230 | 652.61 | 48 | 268.83 | 8 | 21.95 |
| 13 | Kerala | 198 | 466.85 | 14 | 84.62 | 6 | 60.40 |
| 14 | Madhya Pradesh | 85 | 336.33 | 8 | 41.16 | 3 | 24.20 |
| 15 | Maharashtra | 234 | 599.47 | 27 | 207.08 | 4 | 15.25 |
| 16 | Manipur | 96 | 105.63 | 8 | 5.45 | 3 | 2.75 |
| 17 | Meghalaya | 98 | 181.50 | 3 | 30.71 | 9 | 3.28 |
| 18 | Mizoram | 88 | 190.32 | 16 | 14.76 | 3 | 15.50 |
| 19 | Nagaland | 86 | 181.39 | 8 | 20.47 | 6 | 12.40 |
| 20 | Orissa | 161 | 156.76 | 6 | 7.30 | 7 | 40.97 |
| 21 | Punjab | 78 | 65.26 | 23 | 111.40 | 4 | 5.75 |
| 22 | Rajasthan | 49 | 27.26 | 10 | 23.85 | — | — |
| 23 | Sikkim | 68 | 202.75 | 12 | 35.60 | 5 | 15.20 |
| 24 | Tamil Nadu | 147 | 338.92 | 12 | 77.70 | 1 | 6.60 |
| 25 | Tripura | 8 | 9.85 | 3 | 16.01 | — | — |
| 26 | Uttar Pradesh | 211 | 267.06 | 8 | 21.50 | 1 | 3.60 |
| 27 | Uttaranchal | 354 | 1478.24 | 75 | 72.45 | 25 | 25.17 |
| 28 | West Bengal | 145 | 182.62 | 20 | 92.26 | 3 | 5.60 |
| 29 | A & N Islands | 6 | 6.40 | 1 | 5.25 | — | — |
| | Total | 4,233 | 10,324.37 | 514 | 1693.44 | 159 | 488.79 |

Table 7
Capital cost and generation cost of various source of energy

| Sl. No. | Sector | Capital cost (million Rs./MW) | Cost of generation (Rs./KWh) |
|---|---|---|---|
| 1 | Small hydro | 30–60 | 1.00–2.00 |
| 2 | Wind energy | 35–40 | 2.00–2.75 |
| 3 | Biomass power | 30–40 | 1.75–2.00 |
| 4 | Bagasse co-generation | 25–30 | 1.75–2.00 |
| 5 | Biomass gasification | 25–30 | 1.25–1.50 |
| 6 | Solar PV | 250–300 | 10.00–12.00 |

Table 8
Potential and installation of renewable energy sources [7]

| Sl. No. | Sector | Potential | Achievements |
|---|---|---|---|
| 1 | Biogas plants | 12 millions | 3.67 millions |
| 2 | Improved wood stoves | 120 millions | 33.9 millions |
| 3 | Wind | 45,000 MW | 2980 MW |
| 4 | Small hydro | 15,000 MW | 1693 MW |
| 5 | Biomass power/cogeneration | 19,500 MW | 727 MW |
| 6 | Solar PV | 20 MW/km$^2$ | 85 MW |
| 7 | Waste to energy | 1700 MWe | 46.5 MWe |
| 8 | Solar water heating (collector area) | 140 million m$^2$ | 1 million m$^2$ |

## 6. Conclusions

Like other developing countries, the energy demand in India is increasing rapidly. Continued economic development and population growth are driving energy demand faster than India can produce it. Presently, major share of electricity generation in India is from thermal. RES in India are in abundance, which can fulfill the growing energy demand. The main obstacle to increase the share of renewable sources is the relative high installation cost. With the advancement in technology, RES can be tapped in cost effective and sustainable manner. Awareness of the benefits of renewable energy has been steadily growing and it is expected that the share of renewable energy in the total generation capacity will increase in future.

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